curve for the 10.0 MPa pressure case is below the baseline curve, which indicates that the pressure was not high enough, and the layers moved inwards from the surface of the reel.

Simulations were performed to investigate the combined effect of variable tension and compliant layers. A model with a compliant layer was used to run different cases of linearly decaying tension. The modulus of the compliant layer was 0.12 GPa, and the modulus of the regular material was 1.637 GPa. The Poisson ratio for both materials was 0.1. The tension was linearly decayed from a starting value of 30.0 N, to values of 25.0, 20.0, 15.0, and 10.0 N, respectively. Plots of the radial and circumferential stress and strain are shown in Figure 26A. The curve for the 30.0 N constant tension case is also shown in the graphs for comparison. The curve on the circumferential strain plot, which corresponds to the 30.0 to 20.0 N tension case, helps to illustrate the effectiveness of the variable tension combined with a compliant layer. The strain in this case is relatively flat, which would correspond to a more uniform distribution of EFL along the length of a buffer tube. Refinements could be made to the tension curve, including non-linear variations, to produce the optimum distribution of strain.

Additional cases were run using the same form of decaying tension, and different values for the modulus of the compliant layer. A linearly decaying tension from 30.0 to 20.0 N was chosen, and the modulus of the compliant layer was varied from 0.08 to 0.13 GPa, in increments of 0.01 GPa. The modulus of the regular material was 1.637 GPa, and Poisson's ratio for both materials was 0.1. Plots of the radial and circumferential stress and strain are shown in Figure 26B. The circumferential strain plot shows that the modulus of the compliant layer can be tuned to achieve a strain distribution with little variation.

The effect of the shape of the decaying tension curve on the strain distribution was investigated using a series of curves. The tension curves were generated by the following equation:

$$T = T_i - \left(T_f - T_i\right)\left[\frac{r - r_o}{R - r_o}\right]^{\alpha} \qquad (5.2)$$

where T_i is the starting tension, T_f is the final tension, r_o is the inner radius of the layers, R is the outer radius, and α is a coefficient influencing the shape of the curve. The starting tension was taken to be 28.0 N, and the final tension was 20.0 N. Values for the coefficient α were taken to be 0.4, 0.6, 1.0, 1.2, 1.6, and 2.0. The tension curves for these values are shown in Figure 27A.

The model with a compliant layer was used to run the different cases of decaying tension. The modulus of the compliant layer was 0.12 GPa, and the modulus of the regular material was 1.637 GPa. The Poisson ratio for both materials was 0.1. Plots of the radial and circumferential stress and strain are shown in Figure 27B. The tension curve for the α=1.2 case, which is a slight deviation from linear, produces a circumferential strain with very little variation around a constant nominal value.

The results obtained using the concentric layer finite element model were compared to those obtained using the analytical model discussed previously. The material had a modulus of 1.637 GPa, and a Poisson's ratio of 0.1. A constant tension of 30.0 N was used for this case, and there was no compliant layer on the reel surface. The analytical model uses a parameter β to characterize the interaction between the layers of material and the reel. A few values of β were chosen to correspond to the case of a rigid reel that was considered in the

finite element model. Plots of the radial and circumferential stress obtained from FEA and the analytical model are shown in Figure 28. The stresses are in very good agreement when the appropriate choice of β is made.

Comparisons were made between the computed EFL obtained using the concentric layer finite element model and experimentally measured values. The experimental data was obtained from a series of buffering trials of 2.5 mm diameter tubes. In each trial, a 12000.0 km length was taken up on a reel that had an outer diameter of 401.7 mm, and a width of 376.0 mm. The number of layers for this length of tube was determined to be fifty-five from the following formula:

$$L = \sum_{n=1}^{N} \frac{W}{d} \left[d^2 + \pi^2 \left(D + d + (n-1) d\sqrt{3} \right)^2 \right]^{\frac{1}{2}} \tag{5.3}$$

where L is the length, W is the reel width, D is the reel diameter, d is the buffer tube diameter, n is the layer number, and N is the total number of layers. The equation for length was determined by assuming that each buffer tube layer is wrapped around the reel in the path of a helix, with a pitch equal to the buffer tube diameter. Also, perfect packing of the tubes is assumed, as shown in Figure 29.

A concentric layer model was created with an inner radius of 200.0 mm, and fifty-five layers of 2.5mm thickness each. Since each solid layer of material represents a hollow buffer tube filled with gel and fibers, assigning the isotropic material properties for solid polypropylene to each layer is not sufficient. An orthotropic material description was used to allow for a softer modulus in the transverse direction of the tube. A local coordinate system was used to define the material constants for each layer. The local 1 direction was defined through the thickness of the layers, the local 2 direction was defined along the length, and the